NIF NEWS
THE NATIONAL IGNITION FACILITY NEWSLETTER

Reliability and Control of the National Ignition Facility Costs and Schedule

Introduction

The *National Ignition Facility Conceptual Design Report* (CDR), published in 1994, was prepared by a multi-disciplinary team of scientists and engineers from the Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory, Sandia National Laboratories, and the University of Rochester. The CDR extensively describes all aspects of the NIF Project, including the scientific basis, design requirements, and proposed conceptual design of all system components. In parallel with documenting the project design, the team established detailed project cost and schedule estimates using several well-established methods. This process was repeated in 1996 in even greater detail during the Preliminary Engineering Design (Title I) phase of the project.

Defining Project Costs

The Department of Energy (DOE) defines the cost categories for all DOE-funded projects. The final cost estimates for building the NIF Project at Lawrence Livermore National Laboratory (LLNL) are as follows:

- Total estimated cost—$1046 million
- Total project cost—$1199 million

For the NIF Project, the values for both the *total estimated cost* and the *total project cost* (TPC) are in “as-spent” dollars—simply stated, this means that the actual estimates account for characteristics such as inflation, and the estimates include the projected future costs of items and services. The estimates also include a contingency determined by a complex probabilistic process developed by Bechtel Corporation.

As defined by the DOE, the *total project cost* consists of the sum of the *total estimated cost* and *other project costs*. Figure 1 represents these costs and includes a breakdown of the elements in each category.

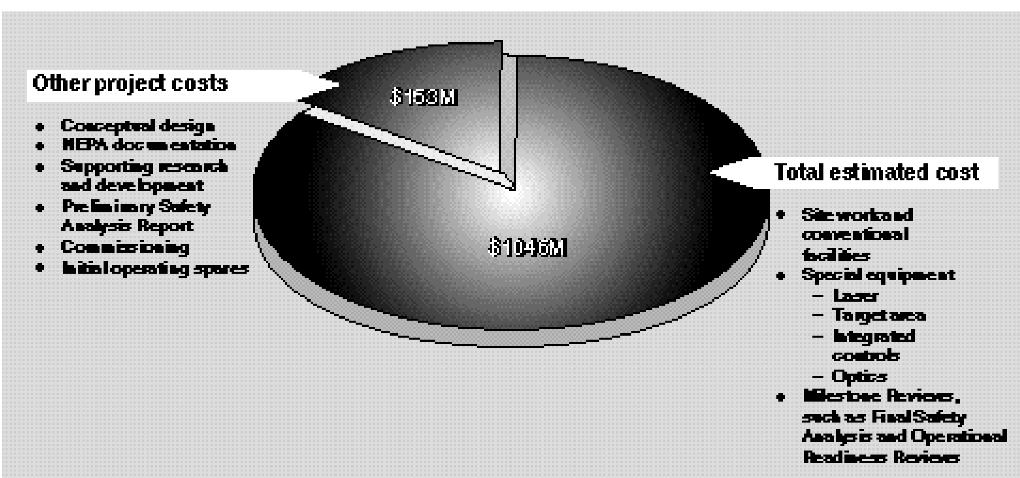

Figure 1. Total Project Cost ($1199 million) consists of the Total Estimated Cost ($1046 million) and Other Project Costs ($153 million) as defined by the DOE.

Operating Costs After Construction

After construction, the NIF operation and maintenance costs will be $64M per year (in fiscal year 1998 dollars). This amount will be for maintaining the facility, ensuring that it is operationally ready and capable of performing the planned experimental program. Other program funds will support the scientists who will design and use the results of experiments for investigating weapons physics, weapons effects, basic physics, and inertial fusion energy.

Funding for the core Inertial Confinement Fusion Program is approximately $180M–$200M per year (in fiscal year 1998 dollars) during construction of the NIF (1996-2003). During construction, a portion of this funding will pay for continuing research on existing facilities, including the technology development leading up to NIF procurements and construction.

Reliability of Estimates

The cost-and schedule-estimating teams applied the following mechanisms to develop precise, thorough, and reliable cost and schedule estimates:

High-confidence-estimating techniques—Almost half of the cost estimates were from catalogs, industry databases, or external vendors. For items with significant uncertainty, we obtained estimates from several potential vendors. Approximately 87% of the 1994 total estimated cost was developed through very-high-confidence methods, shown in Figure 2. The process was repeated in 1996 with an even greater proportion of high-confidence methods used, since the estimate was done much closer to the planned time of procurement.

The 1994 and 1996 estimates were found to be completely consistent. The TPC estimated in 1996 was less than 5% larger than the TPC estimated in 1994, and the change was entirely due to increased capability requested by the user communities, approved by the DOE's Change Control Board, and to stretching the construction schedule by one year to limit peak funding required.

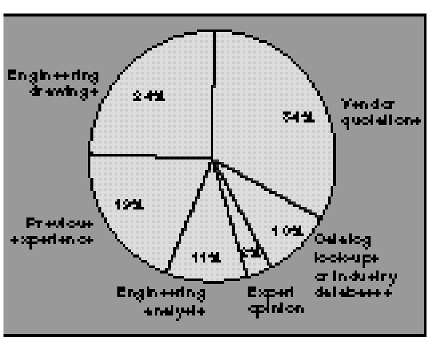

Figure 2. The NIF Project's 1994 total estimated cost was developed through very-high-confidence methods.

The Integrated Project Schedule was determined in the same manner. LLNL worked with experienced vendors to create a "bottom-up" schedule derived from vendor estimates on component fabrication per specified manufacturing processes. More than 4000 NIF components or subsystems were explicitly included. A series of schedule-versus-cost scenarios (such as what are the effects of shorter or longer manufacturing times on cost) was analyzed to produce an optimum, minimum-cost project schedule. Schedule options and contingencies were built in to allow for the expected "unforeseen complications."

Contingency analysis—To account for uncertainties in estimating costs, a detailed *contingency analysis* was performed based on a probabilistic method developed by Bechtel Corporation for use in making business decisions about billion dollar projects. The likelihood that each component would not exceed project estimates was assessed. To have at least a 70% probability that project cost would not exceed estimates, it was determined a contingency of $132 million would be required. That amount has been included in the total project cost estimate.

Reviews of Estimates

The Department of Energy and an independent contractor (Foster Wheeler, USA) reviewed both costs and the detailed Integrated Project Schedule twice. First after the Conceptual Design Study in 1994 and then after the Title I design was completed at the end of 1996. Both the 1994 and 1996 reviews found negligible cost differences between the Independent Cost Estimates (ICE) and the estimates of the NIF Project Office.

The Congressional Research Service, in a March 1997 study, supported the value of NIF to stewardship and the reliability of the cost estimates:

"The potential contribution of the NIF research to the stockpile stewardship program is substantial and diverse.

"Outside review groups have all agreed that these capabilities are critical for the success of the stockpile stewardship program as it is being implemented by DOE.

"Because of the detailed effort that DOE has undertaken to design the NIF and estimate its cost, it appears that there is a reasonable chance that DOE will be able to build the NIF for that amount provided that no more significant changes are made in its requirements."

Historical Record of Delivering Performance on Time and Within Cost

Historical experience—Most of the hundreds of contributors to the design report had successfully generated accurate cost and schedule estimates for other large laser projects constructed within budget and schedule estimates. For example, LLNL's Nova laser—the predecessor to the NIF—was constructed within its cost estimate and on schedule. Nova was the fifth large-scale laser facility for which LLNL had successfully estimated project cost and schedule (Figure 3).

To assure that the laser will deliver the required performance, a prototype NIF beamline was built. The prototype, called the Beamlet laser, consists of a full-scale set of all required hardware, from the photon source to the focusing lens, for one of the NIF's 192 beamlines. The Beamlet, shown on the last photo in Figure 3, has demonstrated the required laser performance and was built within estimated cost.

The Beamlet project has proved that a single full-scale fully integrated beamline could be built that would perform as expected and has tested all potential operating conditions. To meet the NIF's estimated costs, mass-production techniques for the thousands of required optical components are being developed and will be implemented for the NIF. These techniques, developed in conjunction with optics manufacturers, are summarized in the *Manufacturing Readiness Plan*. The plan describes the manufacturing processes that are being developed and implemented to meet the cost estimates for optics components.

A probability analysis for the plan assessed the monetary risk for potential failures in any of the newly developed manufacturing processes. Using this approach, it was concluded that there would be less than 2% total cost exposure.

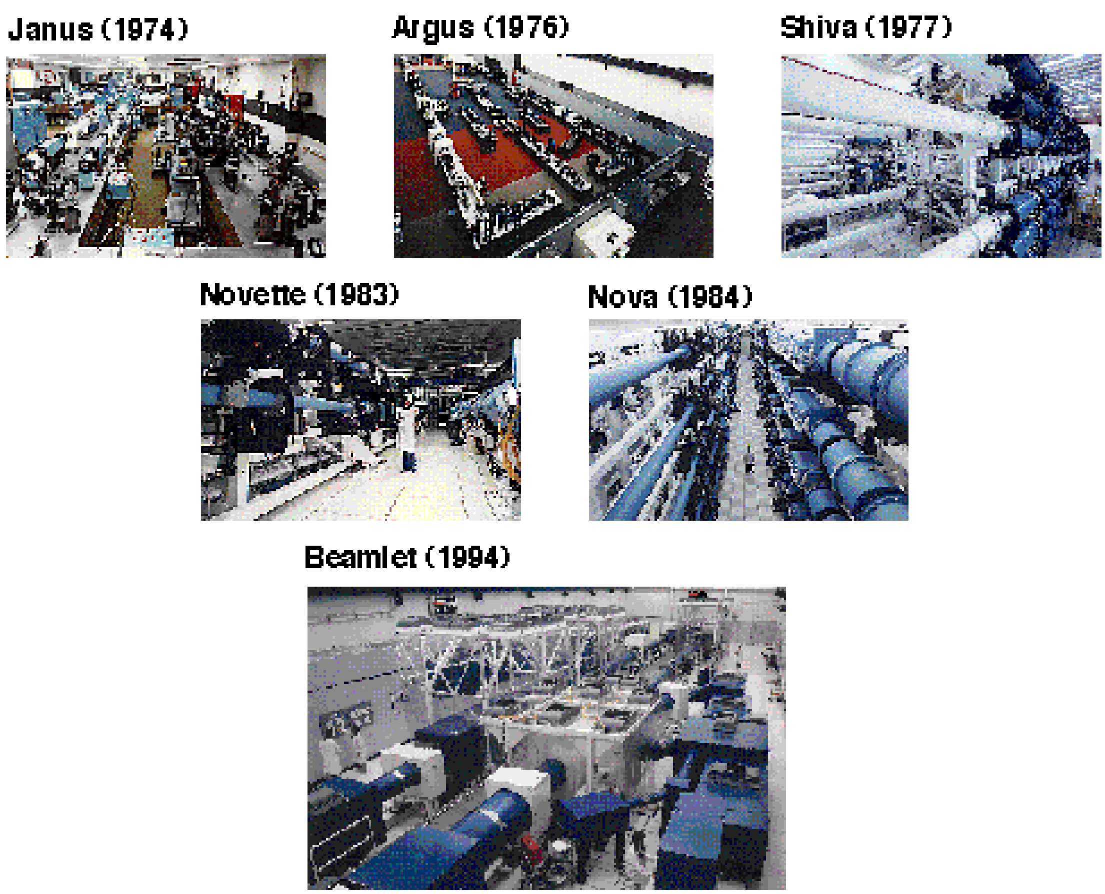

Figure 3. Since 1974, LLNL has built six state-of-the-art laser facilities within performance, schedule, and cost estimates. Beamlet laser is a functional prototype of an integrated NIF beamline and has been used to demonstrate performance specifications and to test operational flexibility and procedures.

Controlling NIF Schedule and Costs

Review of other project experience—Several other large projects have been examined, such as the Superconducting Super Collider in Texas, the Advanced Photon Source at the Argonne National Laboratory, and the Continuous Electron Beam Accelerator Facility in Newport News, Virginia. Several NIF managers met with these project managers to find management and control examples to follow and pitfalls to avoid.

Project control systems—The NIF Project Control Systems are being structured to take advantage of the successes from both LLNL past experience and the other large projects examined. A tracking system that will identify cost and schedule deviations before they become significant has been instituted. Also adopted is a scope and design control process that precludes the possibility of design changes without the appropriate level of scrutiny—a series of change control boards must review and approve system scope and design changes. It was anticipated that scope changes would be requested from user communities between the publication of the conceptual design in 1994 and completion of the Title I design process in 1996. No further changes in requirements will be allowed.

Testing prototype components and manufacturing processes—The NIF laser is intentionally very modular. Prototype modules of each component type are being tested before production manufacturing runs are initiated. For example, an amplifier module consists of a bundle supporting eight individual beamlines in a 4×2 array. Amplifier module prototypes are being tested in the AMPLAB (Figure 4). Similarly, new mass manufacturing techniques will be used for many optical components to reduce costs. Before full production is authorized, full scale production equipment will produce pilot production runs for testing.

Controlling project integration costs—It is recognized that large scale projects have often encountered cost over-runs because integration costs were underestimated even when components costs were well known. NIF's scale will exceed that of previous large laser projects by a significant factor and, therefore, special attention has been paid to integration costs. The final NIF design and construction plan includes several features intended to address this issue: (1) smaller, testable module sizes were designed in; (2) Beamlet integrates full scale hardware from the source to the target chamber (linear integration); (3) component module tests (like AMPLAB) test integration of adjacent beamlines (cross sectional integration); and (4) one complete bundle of eight beamlines will be made operational two years before project completion to test complete integration.

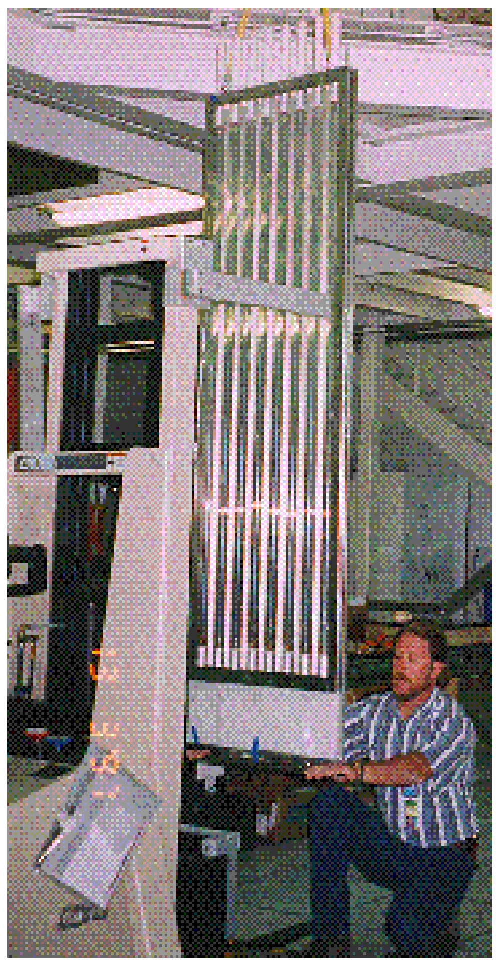

Figure 4. AMPLAB is testing full scale amplifier modules that support bundles of eight beamlines (4×2 arrays).

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